ACCELERATOR EXPERIMENT: Long-Term Vertical Position Stability
of the Main-Ring Quadrupoles

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Motivation

Several complete optical surveys of main-ring quadrupole
vertical positions have been made in the last two years. Ap-
proximately 50 man hours are involved in such a survey. In
this experiment the history of the vertical closed-orbit dis-
tortion is used to evaluate the long-term stability of quadru-
pole positions. The premise is that if the time variation of
the quadrupole vertical position inferred from the closed-orbit
distortion is suitably systematic, then the method may be used
in place of a survey to monitor secular change of position. To
a certain extent a determination from closed-orbit information
may be complementary to an optical survey because their sensi-
tivity peaks in different ranges of azimuthal harmonic of the
quad displacement. That is, the closed-orbit shows particularly
strong response to a distribution of quad displacement with a
twentieth or eightieth harmonic distribution whereas the optical
survey is particularly sensitive to quad-to-quad or every-other-quad
errors. Because there is an insufficient number of position
detectors to respond to harmonics above the fiftieth, the optical
survey would, if comparably accurate, better reflect the important
high-frequency component whereas the closed orbit position should
be more accurate for the lower harmonics. However, this advantage
of the optical survey may be only apparent for two reasons. First,
the misplacement of one or a few quads almost always has a large
low harmonic content which adequately locates the misplaced
magnets. Secondly, the eightieth harmonic of quad displacement

acts as a twentieth harmonic in ΔB and is therefore fit to
good approximation by a method sensitive to the fiftieth
harmonic in ΔB. Because the primary emphasis is on the secular
trend, however, the precise significance of the ΔB distribution
determined at any given time is not crucial to the argument so
long as the method looks in some way at all components of the
quadrupole motion which effect the machine. When the monitoring
is done via the beam behavior this proviso is clearly observed.

Technique

Ten different measurements of the main-ring high field vertical
closed orbit were taken between April 1972 and December 1973[1]
using the split electric induction electrodes[2]. The first four
measurements were made manually[3] with an oscilloscope carried
from service building to service building. A complete measurement
took about four hours and was subject to error from changes in
machine parameters as well as to human recording errors. The
last six measurements have been made with the automatic beam
position sensing system which has shown in recent months, at
least, a high degree of measure-remeasure stability and excellent
predictive power for quadrupole displacement corrections. The
rms uncertainty in vertical closed-orbit measurements is probably
~1 mm.

During the year and a half spanned by the ten measurements,
quadrupole moves[4] were made to improve the vertical orbit dis-
tortion. The data were corrected to remove the effect of these
moves by using the main-ring orbit correction program.[5]

From time to time one or another beam position detector is
inoperative and there are 107 instead of 108 measured values of
the closed-orbit distortion. To permit a uniform comparison of
data with as few as 101 operative detectors all data are fit
to fiftieth order in Fourier series. These fit values of the
closed orbit are used to calculate the quadrupole positions.

The fitted data, corrected for all intentional quadrupole
moves, was then analyzed by the main-ring orbit correction

program[6] to yield the motion required of 102 vertically forusing quadrupoles to minimize the rms orbit distortion. Practically speaking this gives a correction to zero distortion at all locations except the "11" stations where moves were not made. The "11" stations were omitted to provide nearly equal phase advance in between correction locations and to leave a few degrees of freedom to fit for missing detectors.

Observations

Figure 1 compares the April 1972 calculated vertical quad displacement with that calculated for May 1973. Figure 2 compares the May 1973 result with that for November 1973. One can observe that general features persist throughout. The appearance of a few local discrepancies indicate the kind of error the procedure has been heir to particularly in the early stages when human error entered or the automatic system was just shaking down. Had this analysis been done immediately after the data was taken one would have been in a position to recheck the data and equipment, but even without such corrections the errors are few enough to permit good overall comparison.

An example of this possibility of verifying the data is shown in Figure 3 which compares recent measurements. (11/21 and 12/5) With the exception of a single prominent discrepancy the data produced nearly identical results for the vertical quad displacement. This agreement is especially interesting since one set of data was taken at $\nu_y \approx 20\ 1/4$ and one at $\nu_y \approx 19\ 1/4$. The independence of the result on tune lends particular credibility to this measure-remeasure comparison. The error in this particular case is a transcription error in the $\nu_y \approx 19\ 1/4$ data occasioned by the fact that only a fuzzy hard copy of the data existed. Usually the data is made available as a paper tape so that manual transcription is not necessary.

Conclusion

The conclusion suggested from Figures 1 and 2 that the main-ring vertical position has been reasonably stable becomes even stronger when all of the data are superposed. This has been

done by making transparencies of the plots. With the exception of a few ephemeral "glitches" it appears that there has been little significant motion secular or otherwise. One finds a vertically focusing quad distribution with ~ 1/2 mm rms and 2 mm max with sufficient repeatability that one can almost believe that it represents the real configuration of the ring. However, it must be remembered that only the focusing quads have been considered. Because ΔB may arise from an opposite motion of the defocusing quads one could actually be moving opposite to the correct direction in terms of available aperture if one were to move quads according to the calculated results. This remark does not in the least detract from the usefulness of this technique as a monitor of the time dependence of vertical motion with important azimuthal harmonic content.

References

1.

$$\nu_y \simeq 20\ 1/4 \begin{cases} 72/4/14 \\ 72/5/28 \\ 72/7/9 \\ 72/11/17 \end{cases}$$ manual measurements made with an oscilloscope in each service building

$$\begin{cases} 73/5/15 \\ 73/5/17 \\ 73/8/2 \\ 73/8/30 \\ 73/11/21 \end{cases}$$ automatic measuring system

$$\nu_y = 19.286 - 73/12/5$$

2.   Experiment #10

3.   R. Stiening
     S. Mori
     D. Jovanovic

4.   Main-Ring Vertical Moves

72/4/13	C25	−.040"		72/10/24	D11D	.040"
	F25	−.040"			F45	−0.38"
					F47	−.050"
72/5/2	A18	.043"				
	A43	.016"		73/5/17	B25	−.030"
	D23	.077"			F27	.041"
	D47	−.047"				
	F43	.050"				
	F45	.036"				

5.   TM-329, page 5 program option 4

6.   TM-329, page 5 program option 5

FIGURE 1

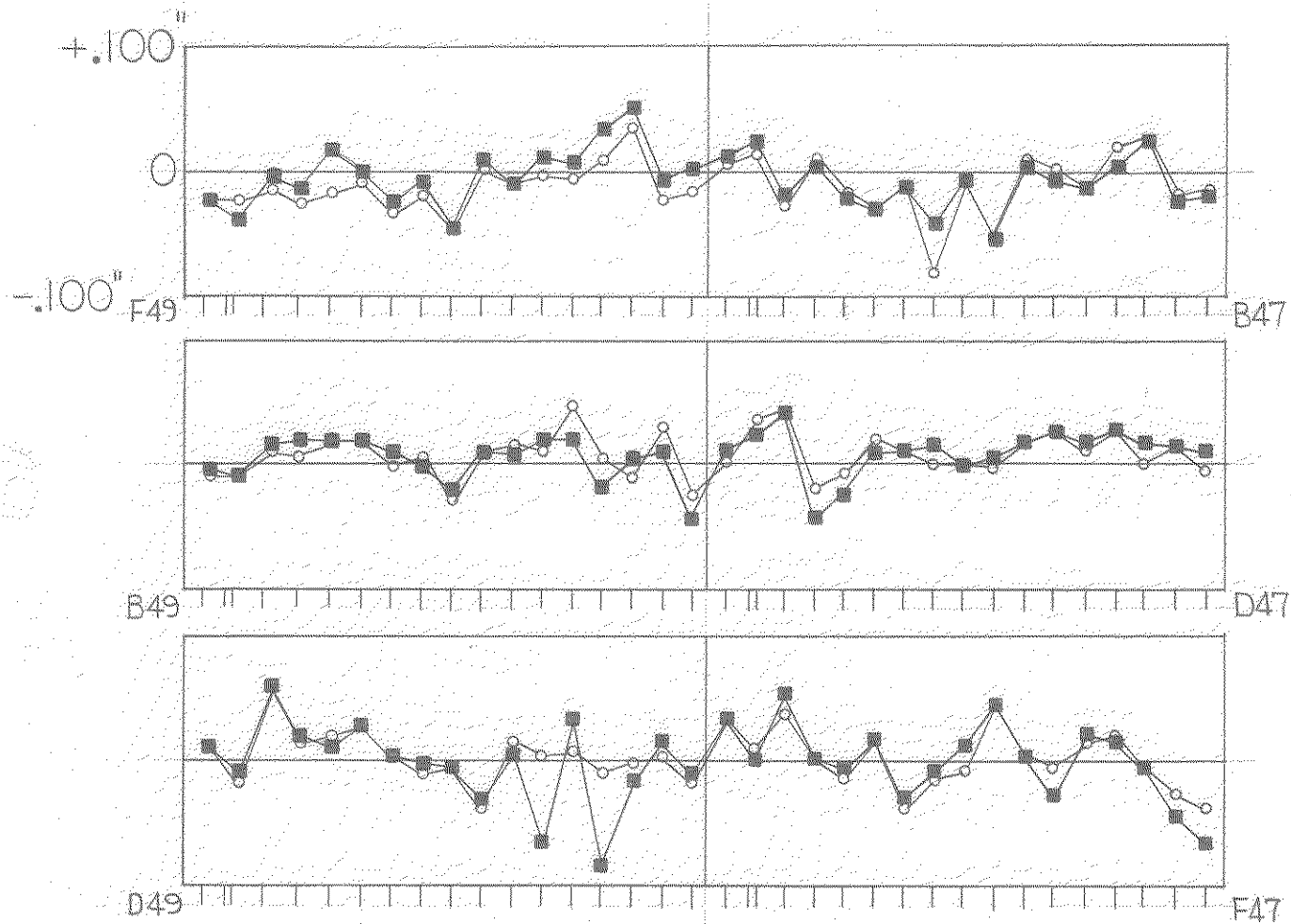## MAIN RING VERTICAL QUADRUPOLE DISPLACEMENT
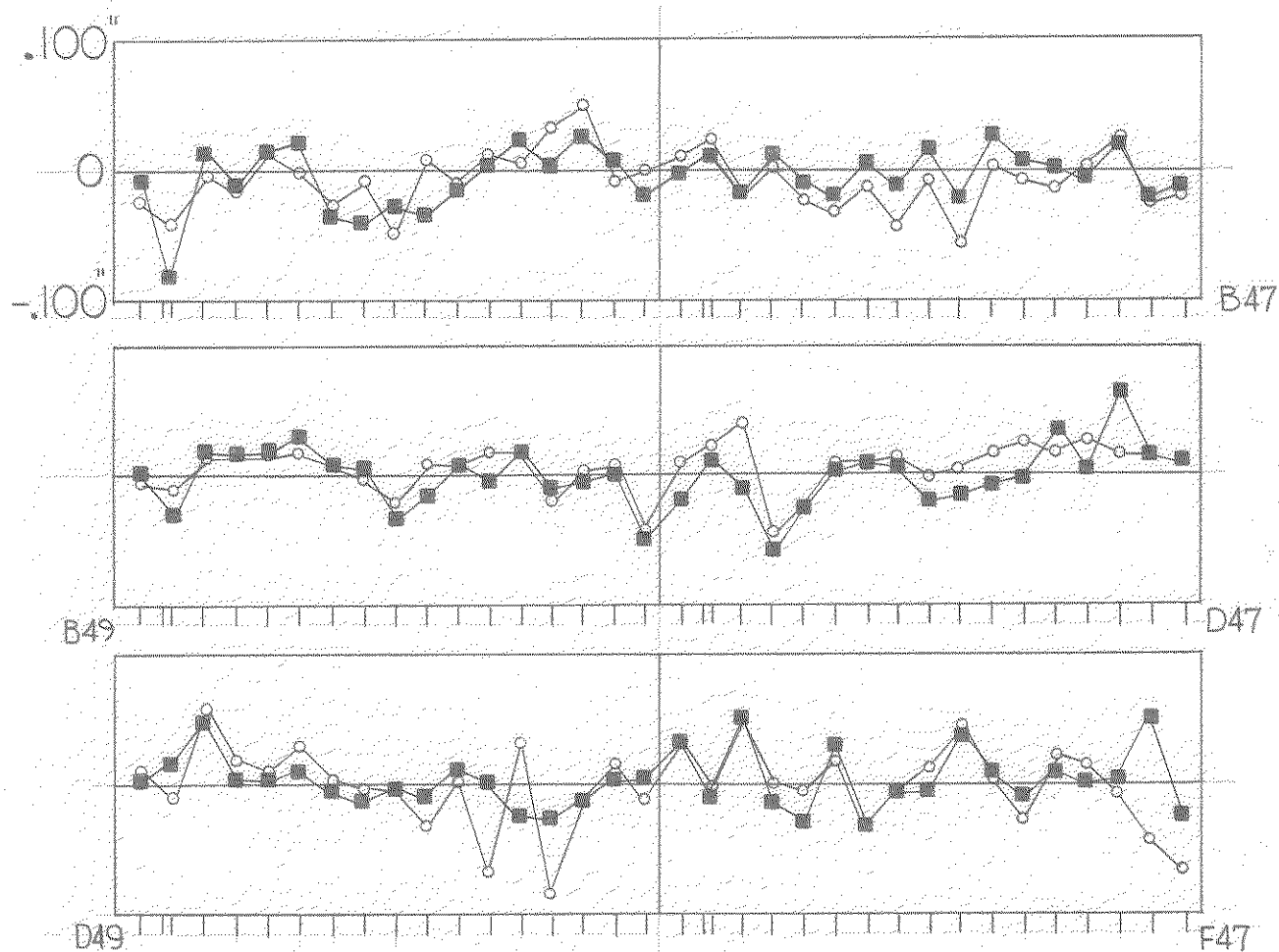
- ■ 1972 APRIL 14 $\nu_y = 20.3$
- ○ 1973 MAY 17 $\nu_y = 20.27$

FIGURE 2

MAIN RING VERTICAL QUADRUPOLE DISPLACEMENT
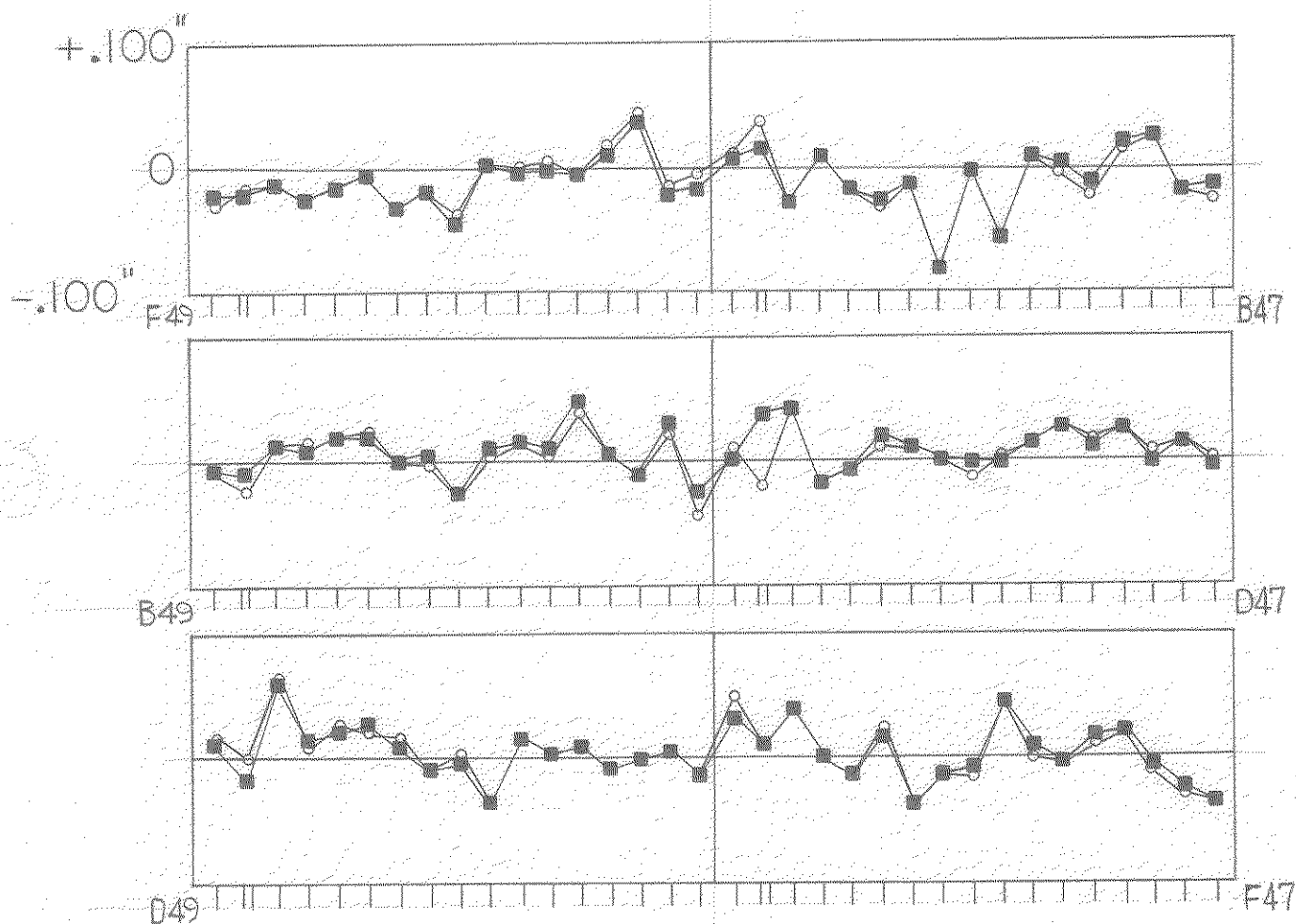

■ 1973 MAY 17 $\nu_y = 20.27$

○ 1973 NOVEMBER 21 $\nu_y = 20.27$

FIGURE 3

MAIN RING VERTICAL QUADRUPOLE DISPLACEMENT

■ 1973 NOVEMBER 21 $\nu_y = 20.27$

○ 1973 DECEMBER 5 $\nu_y = 19.286$